DIVISION OF CONSTRUCTION AND RESEARCH
TRANSPORTATION LABORATORY
RESEARCH REPORT

DEVELOPMENT AND EVALUATION OF RAISED TRAFFIC MARKERS 1971-1974

FINAL REPORT
CA-DOT-TL-5152-3-75-20
DECEMBER 1975

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Prepared in Cooperation with the U.S. Department of Transportation,
Federal Highway Administration

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CALIFORNIA DEPARTMENT OF TRANSPORTATION

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16. ABSTRACT

Evaluation and development of traffic delineators by the State of California, is a continuing project. Six reflective and three combination reflective and nonreflective pavement markers were evaluated and are described in this report. None of the new raised reflective pavement markers submitted to the Laboratory for testing and evaluation have shown better performance than the current State adopted ceramic and retroflective cube corner markers.

One combination day/night ceramic marker which was tested is being recommended as an alternative to the presently specified system in median areas or on low volume roads.

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STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF CONSTRUCTION AND RESEARCH
TRANSPORTATION LABORATORY

December 1975

FHWA No. D-5-14
TL No. 635152

Mr. C. E. Forbes
Chief Engineer

Dear Sir:

I have approved and now submit for your information this final research project report titled:

DEVELOPMENT AND EVALUATION OF RAISED TRAFFIC MARKERS, 1971-1974

Study made by . . . . Concrete Branch

Under the Supervision of . . . . D. L. Spellman

Principal Investigator . . . . T. L. Shelly

Co-Investigator . . . . B. K. Beede

Report Prepared by . . . . B. K. Beede

Very truly yours,

George A Hill

GEORGE A. HILL
Chief, Office of Transportation Laboratory

Attachment

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ACKNOWLEDGEMENTS

The authors wish to express their appreciation to the many individuals who have participated in the development and evaluation of pavement markers. Special mention is deserved to Mr. Enrico Maggenti for his expert help in the many field installations made over the last years to Mr. James A. Cechetini for his development of the white portland cement markers, and to Mr. Manuel Fotos for preparation of the specification of Day/Night Ceramic Markers.

The Headquarters Office of Traffic and the District Traffic and Maintenance Department personnel have been very cooperative during the years this study has been in effect.

I. INTRODUCTION

This report contains the results and conclusions of testing and evaluation of raised reflective pavement markers submitted to or developed by the Transportation Laboratory for the California Department of Transportation (CALTRANS) since 1971. Two of the reflective markers included in this report are intended for use in snowplow areas.

II. IMPLEMENTATION

A specification has been prepared for the Permark combination day/night ceramic marker. This has been submitted to the Office of Systems Operation recommending that they be considered an alternative to the presently specified marker system in median areas or on low volume roads.

III. CONCLUSIONS

No markers tested during this phase of the project were equal to the present items used by the State of California, although at least one shows considerable promise.

Portland cement/aggregate (glass beads) buttons and wedges show a marked decrease in nighttime reflectance and some decrease in daytime visibility after one year of service. The decrease in reflectance is due to the glass beads at the surface becoming chipped and/or cracked. By the time the deeper beads are exposed enough to act as a retroreflector, they, too, are damaged by traffic. The net result is a marker with a very low nighttime reflectance. This rougher surface also decreases daytime visibility somewhat.

Observations during daytime indicate that after 2 to 3 years service, the portland cement buttons and wedges are, overall, inferior to the standard ceramic marker for delineation, although under certain lighting conditions, they are superior to the ceramic units.

A new case design of a ceramic day and night marker with an enclosed reflective tape behind a clear acrylic rod has been shown to have better durability than the earlier designs evaluated in the last report (1968-1971). This new design <u>does</u> have premature failure in reflectance under heavy freeway traffic due to failure of the seal of the reflective tape behind the acrylic rod. Field inspections of a 1/2-mile freeway installation indicate that after three years, 40-50% of the markers in the truck lane have little or no nighttime reflectance; however, the markers in the high speed lanes are performing better (95% good) indicating that these markers might be satisfactory in some locations. Evaluation of these markers will continue with what is hoped to be an improved seal.

Coating of badly scratched or sand abraded standard reflective markers with a clear lacquer does restore some reflectance. However, none of the coatings tested were durable enough to maintain the restored reflectance for more than a few days when exposed to heavy freeway traffic.

IV. BACKGROUND

Beginning in 1954, the Transportation Laboratory (Materials and Research Department) began making experimental installations of raised markers to provide daytime and nighttime wet weather visibility. A painted line is nearly invisible under these latter conditions. The first markers tested experimentally were epoxy or polyester plastic, containing glass beads and a white pigment. After installing and observing many test sections, the first raised marker system was adopted in 1965 for all nonsnowplow areas. It consisted of four white nonbeaded (nonreflective) epoxy or polyester markers placed three feet apart followed by a 15-foot gap, and an acrylic cube corner reflective marker every 48 feet on tangents and 24 feet on curves. This acrylic cube corner reflective marker was much more effective for nighttime visibility than the beaded epoxy and polyester marker first tested. In this system the white nonbeaded marker provides daytime dry weather visibility and some nighttime wet weather visibility. The reflective acrylic markers provides nighttime dry and wet weather visibility.

In 1966, the use of the ceramic nonreflective marker was adopted as a result of our research, which showed that the ceramic markers accumulates less tire stain than the epoxy or polyester type, and maintains a gloss, even when stained, which provides adequate delineation.

Many markers have been tested, including snowplow-resistant marker and combination daytime/nighttime markers which have a white surface for daytime visibility and a reflective surface for nighttime visibility incorporated into a single unit.

This report concludes a series of three reports covering the work performed under a continuing federally funded project. The first report, issued in June 1968, discussed the preliminary work leading to the statewide adoption of a raised marker system for traffic lane delineation. The second report (2), published in October 1971 covers the evaluation, including retention and durability, of many types of markers texted between 1968 and 1971. This final report covers the evaluation of pavement markers submitted to or developed by the Transportation Laboratory of the California Department of Transportation (Caltrans) in the period 1971-1974.

V. NEW MARKERS TESTED

A. Cement Buttons and Cement Wedges

Several thousand white portland cement buttons and wedges were tested (see Figures 1 and 2). These consisted of three different types of formulation. Two of the formulations contained approximately 67% by weight of glass spheres; the third formulation contained approximately 22% by weight of glass spheres. (Appendix)

These markers were tested to see if the surface of the marker would "slough" away the old beads and surface cement under tire action exposing a fresh surface. It was hoped that this would provide a relatively good marker for both daytime and nighttime visibility.

During November 1971, two formulations of white portland cement buttons and wedges were placed on Highway 50 in Sacramento. (One formulation consisted of approximately 22% glass spheres and the second formulation had approximately 67% glass spheres.) This installation, including alternating pattern of standard ceramic markers for control, contains approximately 2000 markers. For further comparison, standard cube corner reflective pavement markers were placed throughout the installations on 48-foot centers.

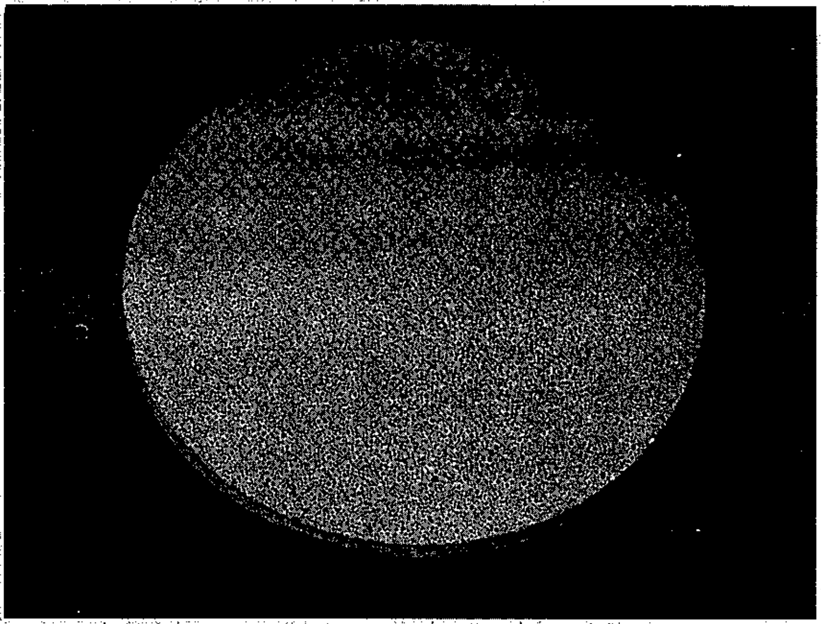


Figure 1. New cement pavement marker showing glass beads.

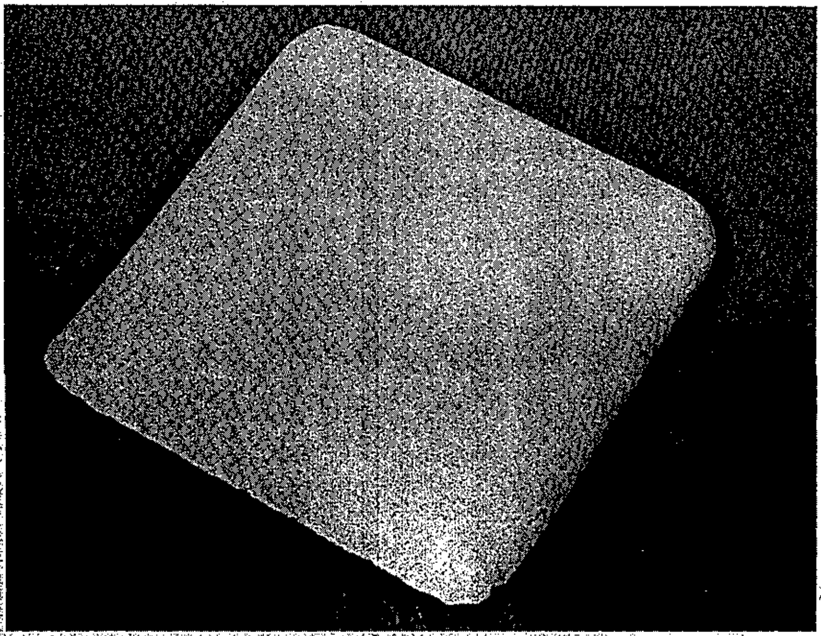


Figure 2. New cement wedge.

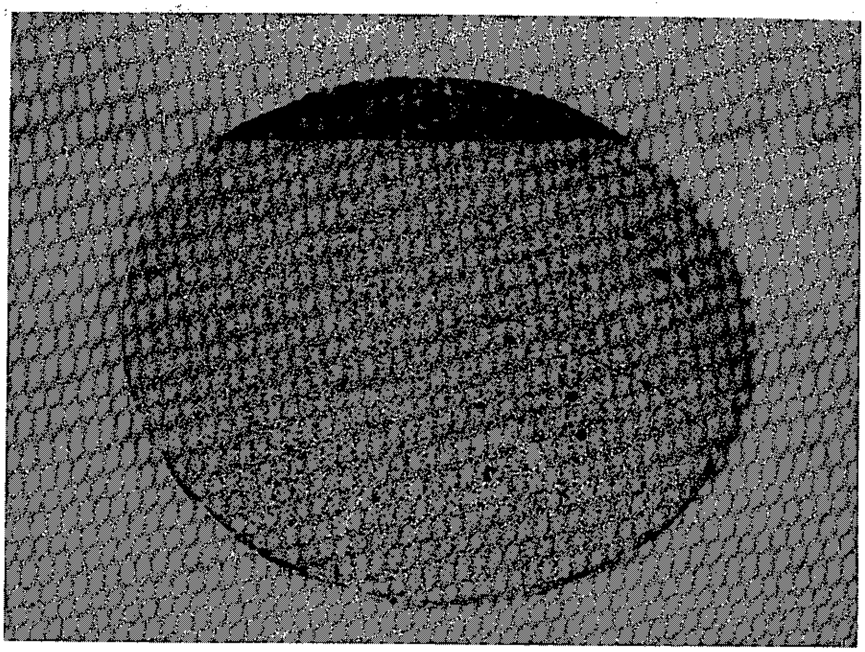


Figure 3. Cement pavement marker. Removed from experimental test section after 2 years service. Note overall gray coloration which tends to match highway pavement.

1. Nighttime Visibility

Nighttime observations of the cement buttons and cement wedges when they were new, indicated that the cement wedges and buttons containing 67% glass spheres were far superior in reflectance to those containing 22% glass spheres. Attention was then focused on the formulations containing 67% glass spheres.

The initial nighttime observation also showed that the wedges were more visible than the buttons. This is due to the wedge having a larger surface area visible toward traffic than the round buttons.

When new, all cement markers containing the higher percentage of beads were more visible at night than the ceramic markers. However, after 2 to 3 years service reflectance dropped to the point that they were substantially equal to the ceramic control buttons.

The second installation of cement buttons and wedges using a different formulation was installed near the first test area. It was apparent after the first installation was made that the glass beads had a brownish color which seemed to decrease the nighttime effectiveness.

The second formulation contained beads that did not have this discoloration, but it was determined that after two years on the road no difference in nighttime visibility between the formulations could be detected

A few of the portland cement/glass bead type markers were removed from the road and examined to determine the reason for the loss of reflectance. Microscopic examination showed that virtually all of the exposed beads were so severely damaged that they no longer could function as reflectors. The beads that were just beginning to become exposed were not damaged; however, they were not exposed enough to provide good nighttime visibility (see Figures 4 and 5).

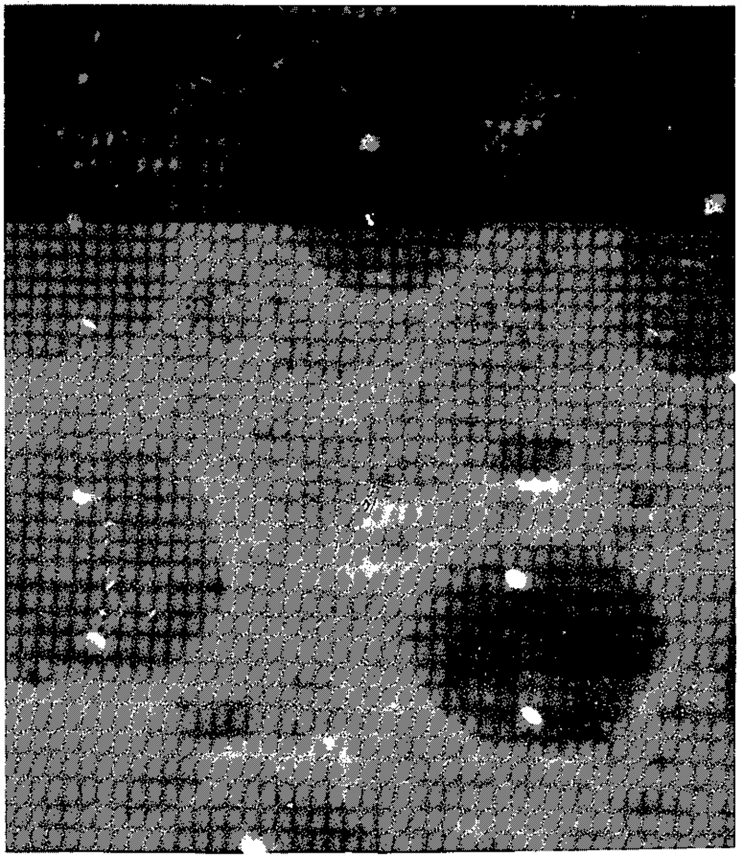


Figure 4. Microscopic photograph of cement marker showing new glass beads.

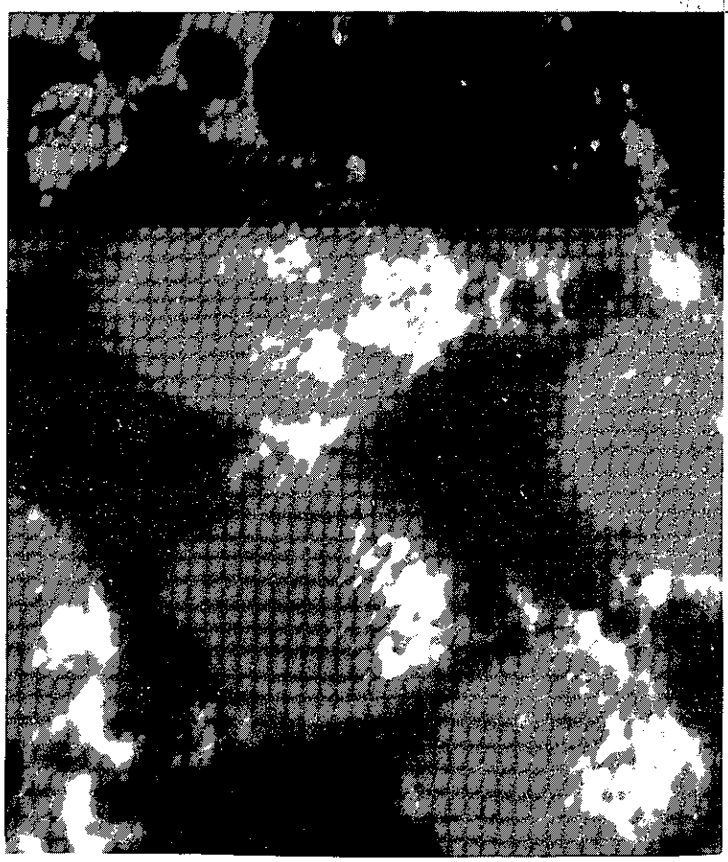


Figure 5. Condition of glass beads after exposure to traffic.

2. Daytime Visibility of Portland Cement/Glass Bead Markers

After being on the roadway for about one year, it was observed that their usefulness as daytime delineators was generally inferior to the control ceramic buttons (see Figure 3). The only time they were equal to, or better than, the ceramic button was when the sun was very low and behind the driver. Under these conditions, the sunlight was reflected by the beads and the whole marker had a tendency to "glow".

During other times of the day, when the sun was not near the horizon, regardless of whether the sky was clear or cloudy, portland cement type buttons provided poorer delineation than the ceramic buttons. Ceramic buttons have a smoother, shiny surface and as a result, "highlights" were more pronounced and seen more often. This highlight effect contributed greatly to their function as daytime delineators. While only of slight significance, the wedges were somewhat more visible than buttons.

It is possible that as the ceramic markers become pitted due to traffic wear, they will collect more dirt in the pits and eventually be less effective than the cement marker, especially during dry weather.

B. Permark

These markers (see Figures 6 and 7) have a ceramic body with a reflective tape enclosed behind a quarter-round acrylic rod. Earlier designs of this marker were not satisfactory because of rapid breakage of the acrylic or glass rod. Modifications of the body design near the rod have resulted in this latest design.

A number of these markers were placed in test areas on the South Sacramento Freeway. They were also placed on Highway 50 near the Transportation Laboratory when this portion of new highway was opened to traffic in 1971.

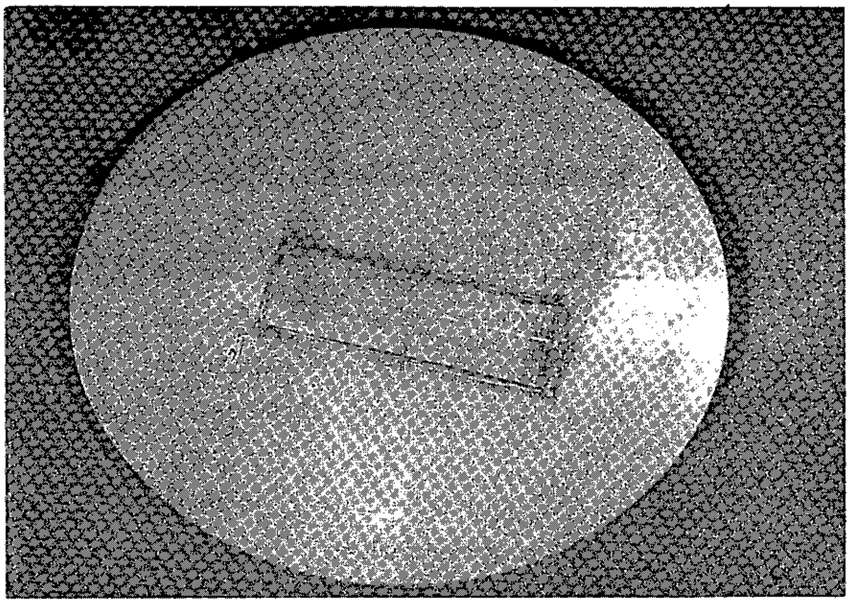


Figure 6. Ceramic marker with reflective tape incapsulated behind 1/4 round acrylic bar. This marker is a slightly modified version of an earlier model.

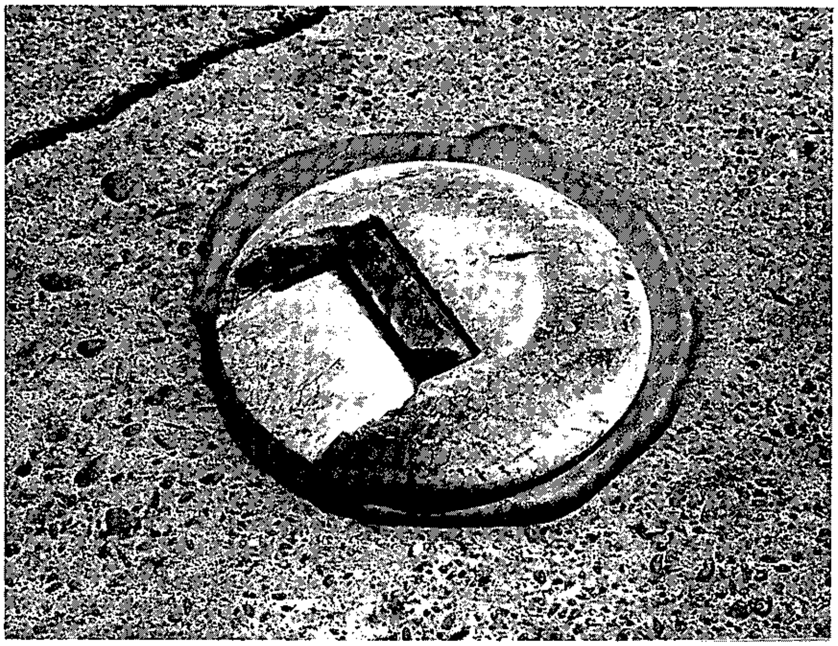


Figure 7. Marker in Figure 6, after one year service in high traffic density area of freeway. This marker was typical of several installed in test section. Nighttime visibility of this unit was severely decreased due to water penetrating the seal between the acrylic bar and reflective tape.

After three years, the markers placed on Highway 50 began to show marked decrease in reflectance. Nighttime observations indicated 40-50% of the units between lanes 3 and 4 had an unacceptable level of reflectance. The initial thought was that the failure in reflectance of these units was due to the acrylic rod breaking; however, after all 50 markers from the South Sacramento test area and several from the Highway 50 area were removed for examination, it was observed that several markers that had acrylic bars which were relatively undamaged did not show any appreciable reflectance either visually or when tested in the Essna Photometer. Closer observations showed that the seal between the acrylic rod and type had failed which permitted moisture and/or mud, road dust, etc., to enter immediately destroying the reflective properties of the tape.

Seal failure between the acrylic rod and reflective tape was not observed in previous models of this marker since the acrylic rod was not as protected and broke before the seal failed.

The daytime visibility of these markers is somewhat less than the standard ceramic marker due to the reduction in ceramic area caused by use of the rod. The durability of these markers is adequate for their use with reasonable confidence at selected locations, such as median areas or lower volume roadways, or on "inside" lanes.

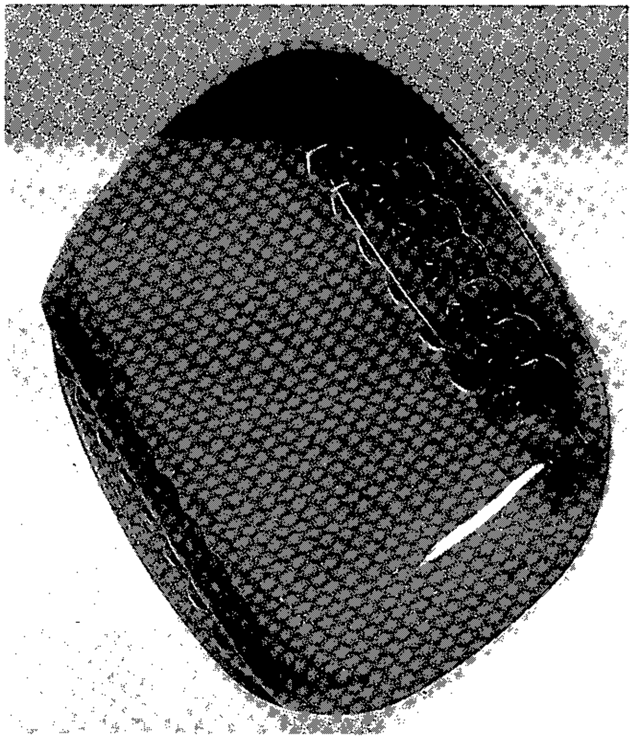


Figure 8

Figure 9

C. <u>Tempered Glass (Anchor Hocking Co.)</u>

These markers have a shell of tempered glass and a wax-type substance for a fill (see Figure 8). Six units were placed on the South Sacramento Freeway in May 1973. Nighttime observations of these markers just after their installation indicated substandard reflectance. After three weeks, four of the six were completely destroyed leaving a black lump of wax on the road (see Figure 9). The remaining two markers were destroyed within three months.

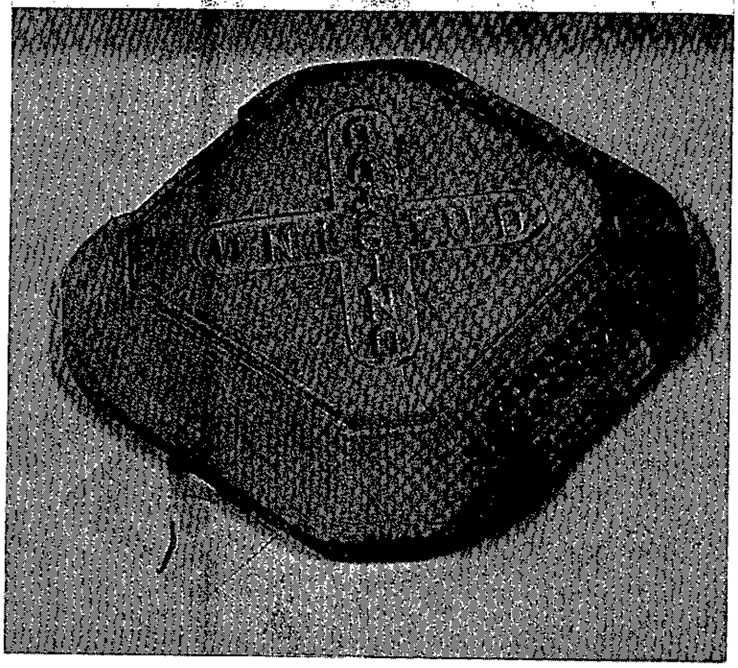


Figure 10
New

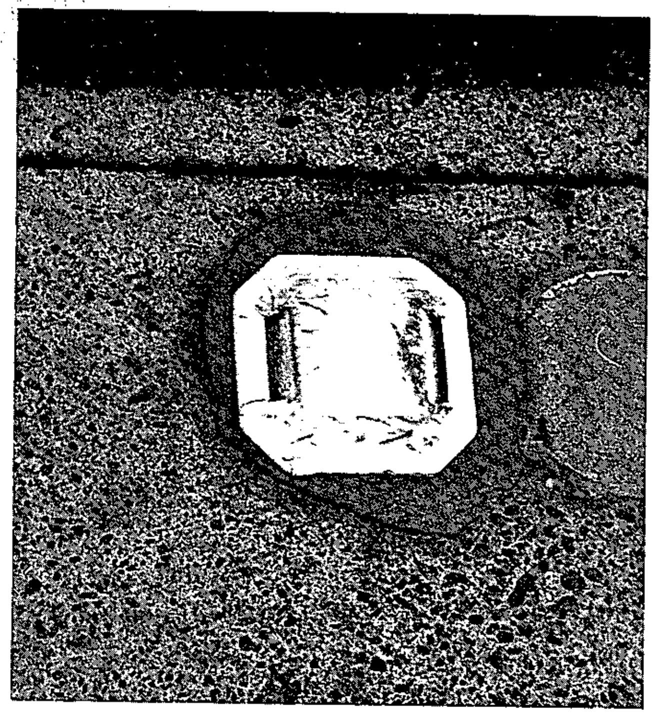


Figure 11
After 6 months
on Freeway.

D. Unistuds

The body of this marker is made of solid rubber-type material with front and rear replaceable reflective units. Each unit, for two-way traffic, consists of 16 small glass eyes imbedded in plastic (see Figure 10).

Several of these reflective markers were placed in a test installation on the South Sacramento Freeway. After two to three months, several of the reflective elements were missing from the markers (see Figure 11).

E. Ray-O-Lite (Air Backed Cube Corner Reflector)

The specific intensity of the clean lens averaged 4-5 candle power/ft. candle which is about the value specified for our standard reflective marker, with approximately 4/10 the lens area. Fifty of these markers were placed on the South Sacramento Freeway during the latter part of 1971. After three months, the cases and lens area of the experimental markers were considerably dirtier than the standard reflective control markers. Several markers were removed from the roadway for close examination. Approximately 80% of all markers examined had some penetration of mud and/or water behind the lens. The presence of moisture in an air backed retroreflector destroys the reflectance. Several markers suffered severe case damage in the lens area and portions of many lenses were missing (see Figures 12 and 13).

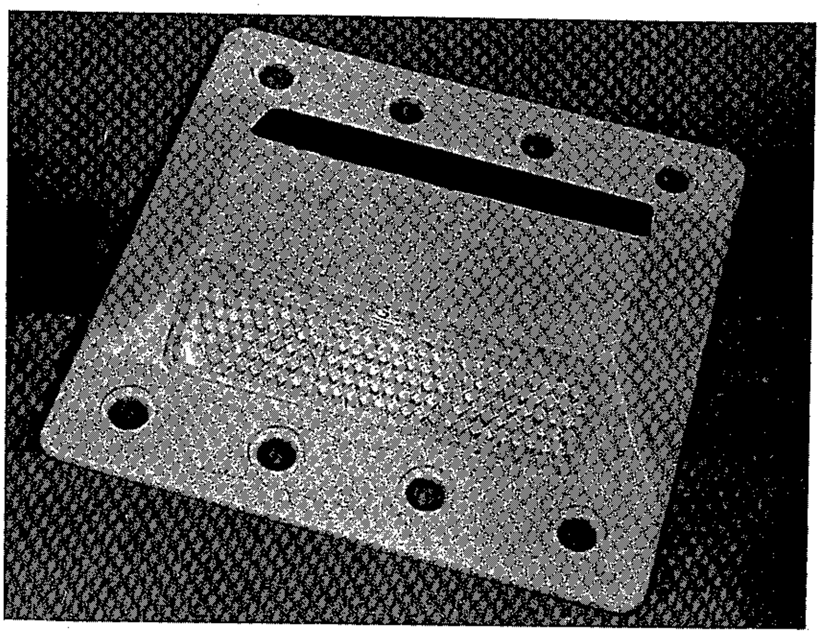


Figure 12. New reflective marker with air backed cube corner reflectors.

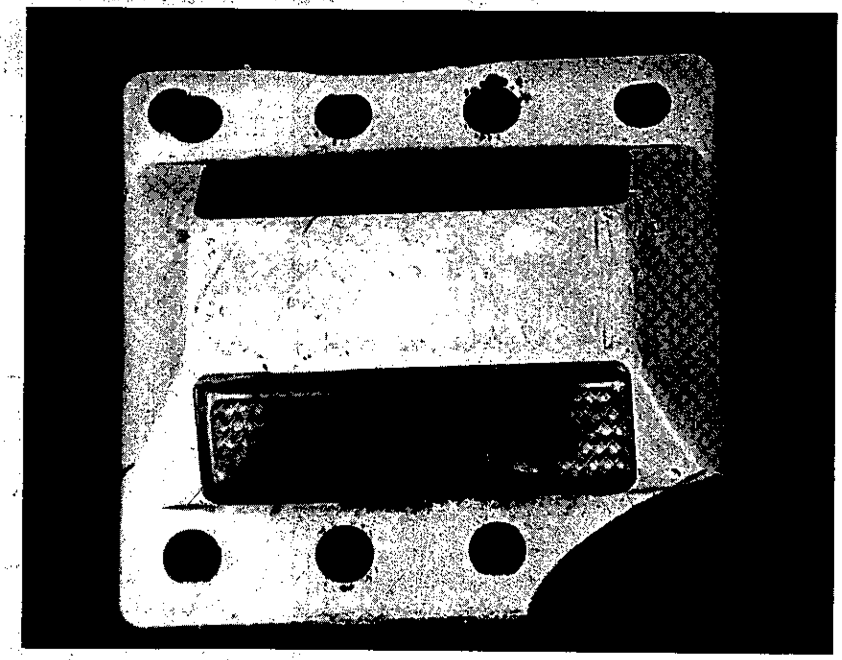


Figure 13. Air backed reflective cube corner markers after three months heavy traffic. Note moisture penetration into rear of lens area which destroys retroreflectance properties.

F. Restoration of Reflectance in Cube Corner Markers

In certain areas of the state, markers are exposed to blown sand which results in the lens area becoming, in effect, sandblasted. If this sandblasting effect is sufficiently strong, the night-time reflectance is reduced to zero. Several methods to restore the lens area without removing or replacing the marker have been tried. The first attempt to restore reflectance in the laboratory was by flashing the surface of the lens with a small torch to remelt the acrylic lens, thus forming a new flat surface.

Remelting the lens did in fact eliminate most small pits and scratches and restored some reflectance, but is not generally recommended as a practical way to refinish acrylic plastic due to the time and care involved.

Later, markers roughened by traffic or by sand were sprayed with a transparent coating. Several coatings were tried with approximately equal results. Krylon No. 1301 crystal clear acrylic was applied as an aerosol. A PVC cement was painted on with the supplied applicator. Bee Chemical LS-123, a clear coating, was applied to the lens area with a small paint brush. In the laboratory, some improvement in reflectance was achieved, however, field application was not encouraging. A small section of 3-5 year old standard reflective pavement markers on the South Sacramento Freeway was chosen for application of the above coatings. They were visible at night prior to coating, but were beginning to show deterioration. All of the markers that were to be coated and a few extra for control purposes were cleaned with a mild soap solution. Krylon 1301, LS-123, and PVC Cement was applied to a total of 30 reflective markers.

The coated markers were observed the night after coating from an automobile and no visual difference in reflectance could be detected between the cleaned, coated markers and the cleaned control markers.

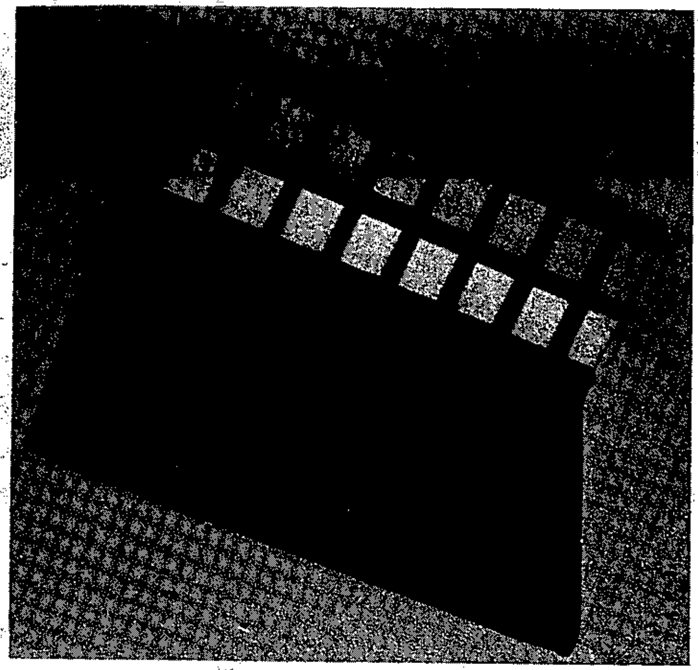


Figure 14

G. 3M Rubber Flaps for Temporary Delineation

These rubber units were designed primarily for use where only temporary delineation is required. The reflective area consists of two reflective tapes -- one for dry nighttime reflectance and one for wet nighttime reflectance (see Figure 14). The specific intensity of the dry tape is about 1.0 and the specific intensity of the wet tape is about 0.5. The units are supplied with butyl rubber adhesive.

Fifteen units were placed on the South Sacramento Freeway during 1972. Five units were placed on uncleaned pavement and the remaining units were placed on wire brushed and primed pavement. The units that were placed over uncleaned pavement remained in place until it rained (approximately one month). Most of the remaining units stayed in place an additional month and were then removed for examination. After two months of heavy freeway traffic, the units that were recovered showed significant wear in the reflective element area.

Rubber flap type markers, properly installed, should be satisfactory where temporary delineation is required, such as during construction or for any other activity requiring temporary changes in lane lines.

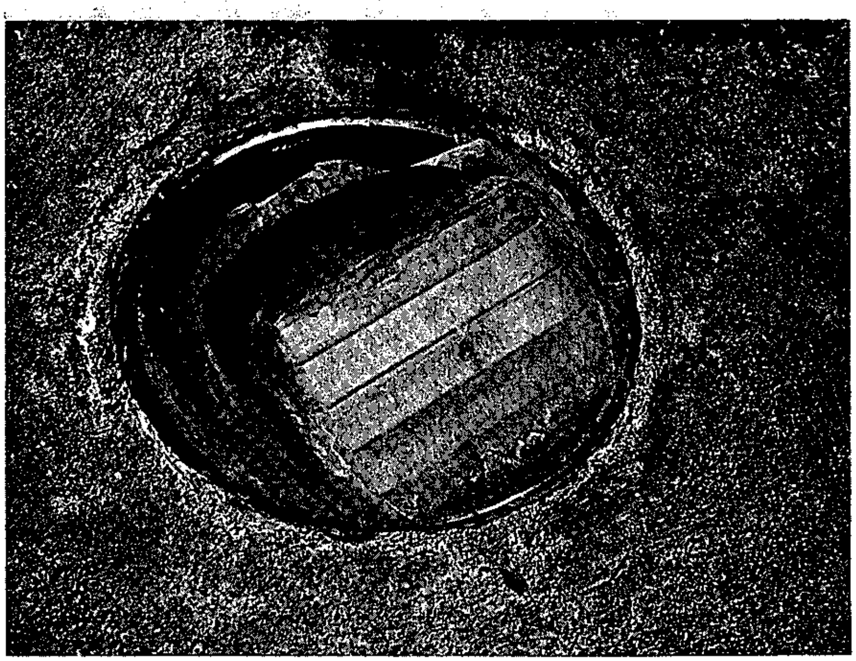


Figure 15

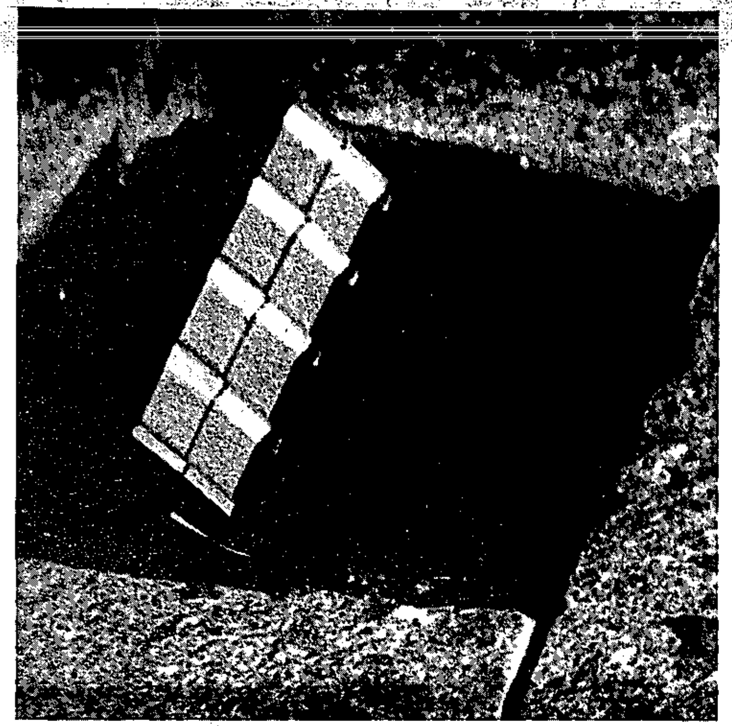
H. Rowlands Marker for Snowplow Areas

This marker was designed for installation in areas where there is snowplow activity. The marker consists of a hollow steel base 4 inches in diameter and 3 inches high. Inside this base is an air backed cube corner retroreflector mounted at an angle facing traffic. Atop this unit is a clear flexible cover with a prismatic lens molded in front (facing traffic). The prismatic lens acts as a diagonal mirror for the cube corner retroreflector (see Figure 15).

When the top of this unit is hit by either an automobile tire or snowplow blade, it is supposed to collapse and allow the object to pass over without damage to the marker. Once the object is clear, internal air pressure causes the top to "pop" back to the original position.

Six units were installed on Interstate 80, five miles east of Donner Summit in February 1974. The markers were subjected to several passes of a snowplow blade within 10 days of their installation.

When observed, five of the test markers had torn tops which allowed water to enter the case. The remaining marker was intact and probably functional.



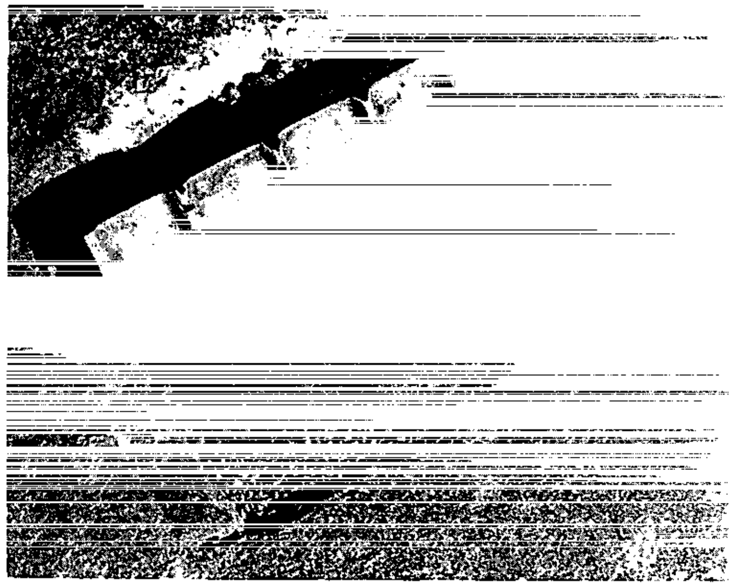


Figure 16
New

Figure 17
After Snowplow Activity

I. <u>3M Rubber Flaps for Snow Areas</u>

These are almost identical with the temporary rubber flaps described earlier. Six units were installed on Interstate 80 with the Rowland snow markers. A depression 4 x 5 x 3/8-inch was cut in the highway for each marker. The pavement was primed with 3M-1357 contact cement and an extra layer of butyl rubber added to aid in smoothing out the bottom of each cut.

These markers were evaluated along with Rowland's snow marker. After several passes with a snow blade, only one marker remained on the road. This marker suffered major damage to the reflective portion and would be ineffective as a nighttime delineator (see Figures 16 and 17).

REFERENCES

1. Shelly, T. L.; Rooney, H. A.; and Beede, B. K.
"Development and Evaluation of Raised Traffic Lane Markers, 1968 to 1971"
State of California, Department of Public Works, Division of Highways, Materials and Research Department, June 1968, Research Report No. 635152.

2. Shelly, T. L.; and Rooney, H. A.
"Development and Evaluation of Raised Traffic Lane Markers, 1953 to 1968"
State of California Department of Public Works, Division of Highways, Materials and Research Department, June 1968, Research Report No. 635152.

APPENDIX

Following are the formulas for the white portland cement beaded concrete buttons and wedges made in the Laboratory for installation on U.S. 50 from Stockton Boulevard eastbound to Power Inn Road:

Type C-1

	Pounds
Glass beads, 1.90 Index of Refraction, Flexolite 40-60	16.2
Liquid Titanium Dioxide Dispersion (50% TiO_2 in water)	9.7
50-mesh Marble White, Pfizer & Company	26.8
White Portland Cement	16.1
Water*	6.0

Type E-1

Glass Beads, 1.90 Index of Refraction, Flexolite 40-60	54.4
Liquid Titanium Dioxide Dispersion, (50% in Water)	8.7
White Portland Cement	15.3
Water*	2.4

*Water will vary slightly from these values.

The following is the formula for white portland cement beaded concrete buttons and wedges made in the Laboratory for a second experimental installation on Highway 50 starting at Bradshaw Road and continuing approximately 2 miles east.

Formula

	Pounds
White Portland Cement	10.7
Glass Beads* (Federal Specification TT-B-1325A, Type III, Gradation A 1.90 Index of Refraction, obtained from Potters Brothers, Anaheim, California)	42.6
Titanium Dioxide, Dupont R-900, Free Chalking Grade	3.1
Tamol 731, 25% Solution, ml (Rohm and Haas Company)	0.5
Water	6.8

*Must be crystal clear, colorless. No yellowness permitted.

1-25-74

SPECIFICATIONS FOR
DAY/NIGHT CERAMIC PAVEMENT MARKERS

Day/Night ceramic pavement markers shall consist of a heat-fired, vitreous, ceramic base and a heat-fired, opaque, glazed surface to produce the properties required in these specifications. No glaze shall be present on the bottom of the marker. The markers shall be produced from any suitable combination of intimately mixed clays, shales, talcs, flints, feldspars, or other inorganic material which will meet the properties herein required. The markers shall be thoroughly and evenly matured and free from defects which affect appearance or serviceability.

The monodirectional marker shall consist of a round ceramic dome shaped base with a flat area on top and an acrylic rod lens reflector permanently bonded to a protective recess in the base. The marker base shall be 4" in diameter and 11/16" high, see attached drawings for details.

The Bi-directional marker shall consist of a ceramic oblong dome shaped base with a flat area on top (centered) and two acrylic rod lens reflectors (opposite sides) with each lens permanently bonded to a protective recess in the base. The marker base shall be oval shaped 4"± wide x 4-3/4" long x 11/16" high. See attached drawings for details.

The top and sides of either type marker shall be smooth and free of mold marks, pits, indentations, air bubbles, or other objectionable marks or discolorations. The bottom of the marker shall be flat (the deviation from a flat surface shall not exceed 0.05 inch), free from gas bubbles, voids, gloss, glaze, or substances that may reduce its bond to the adhesive.

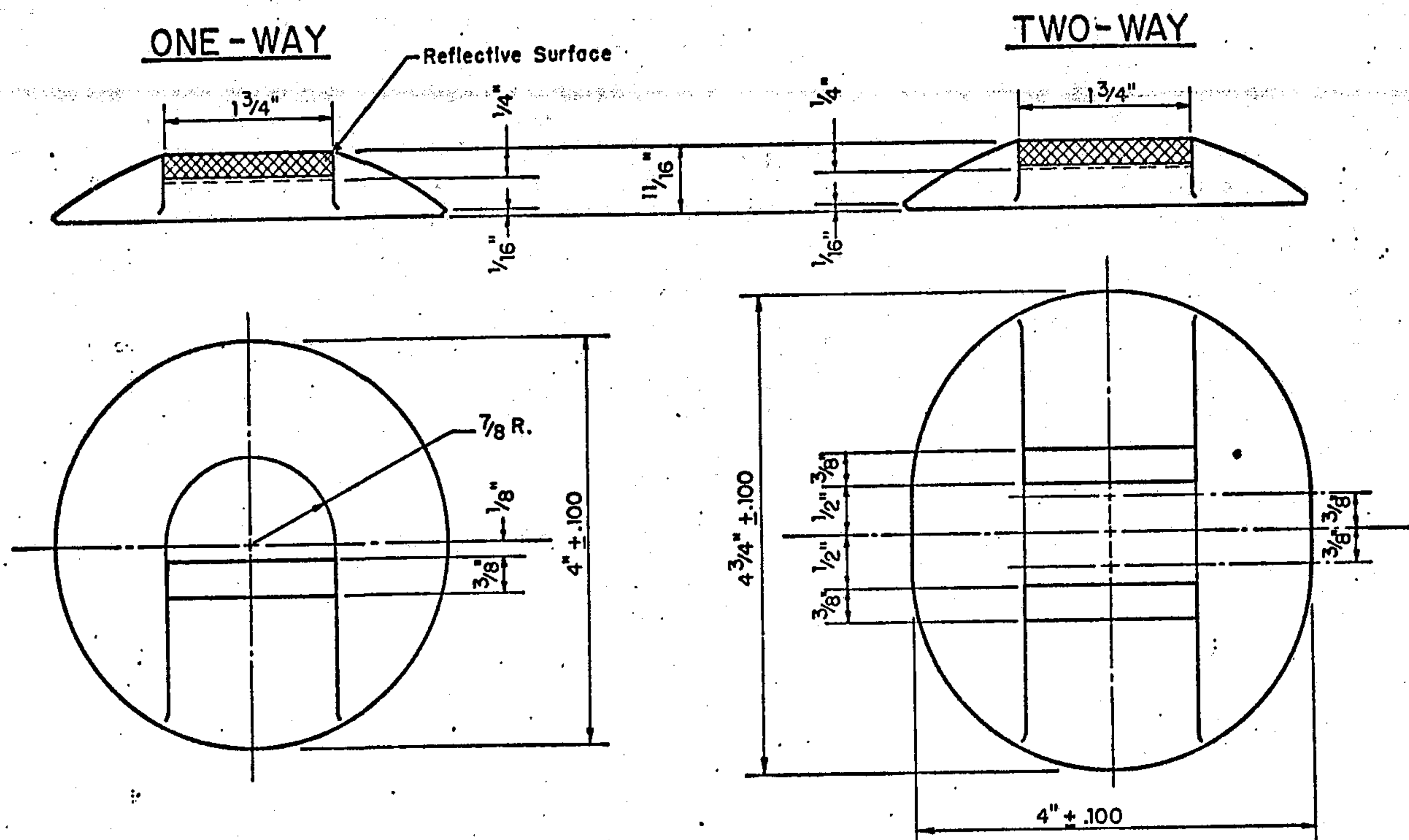
The reflective lenses shall be a 1/4 round (3/8" radius) acrylic rod reflector, approximately 1-3/4" in length. It shall fit flush into the protective recess of the ceramic marker leaving no gaps between the lens and the marker. The lens shall be permanently bonded to the marker and shall not protrude above the top of the marker.

The color of the reflective lens when illuminated by an automobile headlight shall be an approved clear, yellow or red color as designated.

Off-color reflection shall constitute grounds for rejection. Day/Night ceramic pavement markers shall conform to all the properties shown below. All tests shall be performed in accordance with Test Method No. Calif. 669, except as noted.

		Requirement
(1)	Adhesive bond strength to bottom surface of marker using adhesives specified in the following sections of the Standard Specifications: Section 95-2.05, "Standard Set Epoxy Adhesive for Pavement Markers", and Section 95-2.04, "Rapid Set Epoxy Adhesive for Pavement Markers".	700 psi min.
(2)	Glaze thickness	.008 in. min.
(3)	Hardness - Moh	6 min.
(4)	Directional reflectance (White marker only) Glazed surface body of marker.	75 min. 70 min.
(5)	Yellowness index (White markers only) Glazed surface body of marker	0.07 max. 0.12 max.
(6)	Color (Yellow markers only) Purity Dominant wave length Total luminous reflectance (Y value)	 76% to 96% 579 to 585 mu 0.41 min.
(7)	Autoclave Resistance	Glaze shall not spall, craze or peel.
(8)	Strength	1,500 lbs. min.
(9)	Water absorption	2% max.
(10)	85° Specular Gloss (sheen) of bottom of the marker, as determined by Federal Test Method 6103	6 max.
(11)	Lens Reflectance	Specific Intensity

	Clear	Yellow	Red
0° Incidence Angle, Min.	1.0	0.60	0.25
20° Incidence Angle, Min.	0.8	0.50	0.20



NOTE: Tolerances ± 1/16" unless otherwise specified.

STATE OF CALIFORNIA
DEPT OF TRANSPORTATION

DAY/NIGHT CERAMIC PAVEMENT MARKERS

9/74